Claims

[c1] 1.A phosphor comprising oxides of at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof and oxides of at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combination thereof, said phosphor being activated with ions of at least a rare-earth metal comprising at least europium, said phosphor having a formula of $(M_{1-x}RE_x)_y D_2O_4$;
wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x < 0.3$, and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$.

[c2] 2.The phosphor according to claim 1, wherein said phosphor absorbs electromagnetic radiation in a wavelength range from about 350 nm to about 480 nm and has an emission peak in a wavelength range from about 500 nm to about 600 nm.

[c3] 3.The phosphor according to claim 1, wherein said phosphor is further doped with at least an additional rare-earth metal selected from the group consisting of cerium, praseodymium, neodymium, samarium, gadolinium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium.

[c4] 4.The phosphor according to claim 3, wherein said at least an additional rare-earth metal comprises from about 0.001 to about 30 atom percent of a total of said at least an alkaline-earth metal, said europium, and said at least an additional rare-earth metal.

[c5] 5.The phosphor according to claim 3, wherein said at least an additional rare-earth metal comprises from about 0.001 to about 20 atom percent of a total of said at least an alkaline-earth metal, said europium, and said at least an additional rare-earth metal.

[c6] 6.The phosphor according to claim 3, wherein said at least an additional rare-earth metal comprises from about 0.001 to about 10 atom percent of a total of

said at least an alkaline-earth metal, said europium, and said at least an additional rare-earth metal.

[c7] 7.The phosphor according to claim 1, wherein said phosphor further comprises magnesium.

[c8] 8.The phosphor according to claim 7, wherein said magnesium comprises from about 0.001 to about 20 atom percent of said at least an alkaline-earth metal.

[c9] 9.A phosphor comprising oxides of strontium and aluminum, activated with ions of europium, said phosphor having a formula of

$(Sr_{1-x}Eu_x)_yAl_2O_4$;

wherein $0.001 < x < 0.3$ and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$.

[c10] 10.A phosphor blend comprising:

(a)a first phosphor comprising oxides of at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof and oxides of at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combination thereof, said phosphor being activated with ions of at least a rare-earth metal comprising at least europium, said phosphor having a formula of

$(M_{1-x}RE_x)_yD_2O_4$;

wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x < 0.3$, and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$; and

(b)at least an additional phosphor selected from the group consisting of phosphors that are excitable by radiation having wavelengths in a range from about 315 nm to about 480 nm that have a peak emission in at least one of blue, blue-green, green, yellow-orange, and red light wavelengths.

[c11] 11.The phosphor blend according to claim 10, wherein said first phosphor further comprises magnesium in an amount from about 0.001 to about 20 atom percent of said alkaline-earth metal.

[c12] 12.The phosphor blend according to claim 10, wherein said peak emission in said blue light wavelengths is in a range from about 400 nm to about 480 nm.

[c13] 13.The phosphor blend according to claim 10, wherein said peak emission in said blue-green light wavelengths is in a range from about 480 nm to about 500 nm.

[c14] 14.The phosphor blend according to claim 10, wherein said peak emission in said green light wavelengths is in a range from about 500 nm to about 550 nm.

[c15] 15.The phosphor blend according to claim 10, wherein said peak emission in said yellow-orange light wavelengths is in a range from about 550 nm to about 630 nm.

[c16] 16.The phosphor blend according to claim 10, wherein said peak emission in said red light wavelengths is in a range from about 610 nm to about 700 nm.

[c17] 17.A phosphor blend comprising $Sr_{0.8}Eu_{0.1}Al_2O_4$, $Ca_5(PO_4)_3Cl:Mn^{2+}$,Eu^{2+}, and $(Sr,Ba,Ca)_{\Gamma}(PO_4)_{\neg}(Cl,OH):Eu^{2+}$.

[c18] 18.A method for producing a phosphor, said method comprising:
(a)providing amounts of oxygen-containing compounds of at least a rare-earth metals comprising at least europium; at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof; and at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combinations thereof;
(b)mixing together said oxygen-containing compounds to form a mixture; and
(c)firing said mixture in a reducing atmosphere at a temperature and for a time sufficient to convert said mixture to said phosphor having a formula of $(M_{1-x}RE_x)_yD_2O_4$;
wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x < 0.3$, and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$.

[c19] 19.The method according to claim 18 further comprising adding at least a

halide of at least a metal selected from the group consisting of rare-earth metals, strontium, barium, calcium, aluminum, gallium, indium, and combinations thereof.

[c20] 20.The method according to claim 18, wherein said oxygen-containing compounds are oxides.

[c21] 21.The method according to claim 18, wherein said firing is carried out at a temperature in a range from about 900^{0} C to about 1300^{0} C.

[c22] 22.The method according to claim 18, wherein said firing is carried out at a temperature in a range from about 1000^{0} C to about 1100^{0} C.

[c23] 23.The method according to claim 18, wherein said firing is carried out at a substantially constant temperature.

[c24] 24.The method according to claim 18, wherein said temperature is ramped from ambient temperature to a final temperature.

[c25] 25.The method according to claim 18, wherein said firing is carried out for a time from about 1 minute to about 10 hours.

[c26] 26.The method according to claim 18, wherein said firing is carried out in an atmosphere comprising a gas selected from the group consisting of hydrogen and carbon monoxide.

[c27] 27.The method according to claim 18, wherein said firing is carried out in an atmosphere comprising from about 1 to about 3 volume percent hydrogen in nitrogen.

[c28] 28.A method for producing a phosphor, said method comprising:
(a)providing amounts of compounds of at least a rare-earth metals comprising at least europium; at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof; and at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combinations thereof;
(b)mixing together said compounds to form a mixture;

(c)heating said mixture to convert said mixture to a mixture of oxides; and

(d)firing said mixture of oxides in a reducing atmosphere at a temperature and for a time sufficient to convert said mixture to said phosphor having a formula of

$(M_{1-x}RE_x)_y D_2O_4$;

wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x < 0.3$, and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$.

[c29] 29.The method according to claim 28, wherein said compounds are selected from the group consisting of carbonates, nitrates, nitrides, sulfates, sulfites, chlorates, perchlorates, oxyhalides, acetates, citrates, salts of organic acids, and combinations thereof.

[c30] 30.The method according to claim 28 further comprising adding further comprising adding at least a halide of at least a metal selected from the group consisting of rare-earth metals, strontium, barium, calcium, aluminum, gallium, indium, and combinations thereof.

[c31] 31.The method according to claim 28, wherein said heating is carried out at a temperature in a range from about 400^0 C to about 900^0 C.

[c32] 32.The method according to claim 28, wherein said heating is carried out in an oxygen-containing gas.

[c33] 33.The method according to claim 28, wherein said firing is carried out at a temperature in a range from about 900^0 C to about 1300^0 C.

[c34] 34.The method according to claim 28, wherein said firing is carried out at a temperature in a range from about 1000^0 C to about 1100^0 C.

[c35] 35. The method according to claim 28, wherein said firing is carried out at a substantially constant temperature.

[c36] 36.The method according to claim 28, wherein said temperature is ramped from ambient temperature to a final temperature.

[c37] 37.The method according to claim 28, wherein said firing is carried out for a time from about 1 minute to about 10 hours.

[c38] 38.The method according to claim 28, wherein said firing is carried out in an atmosphere comprising a gas selected from the group consisting of hydrogen and carbon monoxide.

[c39] 39.The method according to claim 28, wherein said firing is carried out in an atmosphere comprising from about 1 to about 3 volume percent hydrogen in nitrogen.

[c40] 40.A method for producing a phosphor, said method comprising:
(a)providing a first solution comprising compounds of at least a rare-earth metals comprising at least europium; at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof; and at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combinations thereof, said compounds being selected from the group consisting of nitrates, sulfates, acetates, citrates, chlorates, perchlorates, oxyhalides, salts of organic acids containing 1 to 6 carbon atoms, esters of di-carboxylic acids containing 1 to 6 carbon atoms, salts of aromatic acids having 1 to 2 aromatic rings, acetylacetonates, alkoxides, phenoxides, and mixtures thereof;
(b)providing a second solution comprising a material selected from the group consisting of ammonium hydroxide, ammonium carbonate, ammonium oxalate, methanolamine, ethanolamine, propanolamine, dimethanolamine, diethanolamine, dipropanolamine, trimethanolamine, triethanolamine, or tripropanolamine, and mixtures thereof;
(c)adding said second solution to said first solution to form a precipitate; and
(d)firing said precipitate in a reducing atmosphere at a temperature and for a time sufficient to convert said mixture to said phosphor having a formula of $(M_{1-x}RE_x)_yD_2O_4$;
wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x < 0.3$, and y satisfies a condition selected from the group consisting of $0.75 < y <$

1 and $1 < y < 1.1$.

[c41] 41.The method according to claim 40 further comprising adding at least a halide of at least a metal selected from the group consisting of rare-earth metals, strontium, barium, calcium, aluminum, gallium, indium, and combinations thereof.

[c42] 42.The method according to claim 40 further comprising heating said precipitate at a temperature in a range from about 400^{0} C to about 900^{0} C before the step of firing.

[c43] 43.The method according to claim 42, wherein said heating is carried out in an oxygen-containing gas.

[c44] 44.The method according to claim 42, wherein said firing is carried out at a temperature in a range from about 900^{0} C to about 1300^{0} C.

[c45] 45.The method according to claim 42, wherein said firing is carried out at a temperature in a range from about 1000^{0} C to about 1100^{0} C.

[c46] 46.The method according to claim 42, wherein said firing is carried out at a substantially constant temperature.

[c47] 47The method according to claim 42, wherein said temperature is ramped from ambient temperature to a final temperature.

[c48] 48.The method according to claim 42, wherein said firing is carried out for a time from about 1 minute to about 10 hours.

[c49] 49.The method according to claim 42, wherein said firing is carried out in an atmosphere comprising a gas selected from the group consisting of hydrogen and carbon monoxide.

[c50] 50.The method according to claim 42, wherein said firing is carried out in an atmosphere comprising from about 1 to about 3 volume percent hydrogen in nitrogen.

[c51] 51.A light source comprising:

(a)at least one LED that is capable of emitting a radiation having wavelengths in a range from about 315 nm to about 480 nm; and

(b)a phosphor casting comprising a transparent material and particles of a phosphor blend comprising:

(1)a first phosphor comprising oxides of at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof and oxides of at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combination thereof, said phosphor being activated with ions of at least a rare-earth metal comprising at least europium, said phosphor having a formula of $(M_{1-x}RE_x)_y D_2 O_4$;

wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x < 0.3$, and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$; and

(2)at least an additional phosphor selected from the group consisting of phosphors that are excitable by radiation having wavelengths in a range from about 315 nm to about 480 nm that have a peak emission in at least one of blue, blue-green, green, yellow-orange, and red light wavelengths.

[c52] 52.The light source according to claim 51, wherein said first phosphor further comprises magnesium in an amount from about 0.001 to about 20 atom percent of said at least an alkaline-earth metal.

[c53] 53.The light source according to claim 51, wherein said phosphor casting further comprises particles of a light-scattering material.

[c54] 54.The light source according to claim 51, wherein said peak emission in said blue light wavelengths is in a range from about 400 nm to about 480 nm.

[c55] 55.The light source according to claim 51, wherein said peak emission in said blue-green light wavelengths is in a range from about 480 nm to about 500 nm.

[c56] 56.The light source according to claim 51, wherein said peak emission in said

green light wavelengths is in a range from about 500 nm to about 550 nm.

[c57] 57.The light source according to claim 51, wherein said peak emission in said yellow-orange light wavelengths is in a range from about 550 nm to about 630 nm.

[c58] 58.The light source according to claim 51, wherein said peak emission in said red light wavelengths is in a range from about 610 nm to about 700 nm.

[c59] 59.A light source comprising:

(a)at least one LED that is capable of emitting a radiation having wavelengths in a range from about 315 nm to about 480 nm; and

(b)a phosphor casting comprising a transparent material and particles of a phosphor blend phosphor blend comprising $Sr_{0.8}Eu_{0.1}Al_2O_4$, $Ca_5(PO_4)_3Cl:Mn^{2+},Eu^{2+}$, and $(Sr,Ba,Ca)_5(PO_4)_3(Cl,OH):Eu^{2+}$.

[c60] 60.The light source according to claim 59, wherein said phosphor casting further comprises particles of a light-scattering material.

[c61]

61.A light source comprising:

(a)a plurality of LEDs attached to a reflective panel, said LEDs being capable of emitting a radiation having wavelengths in a range from about 315 nm to about 480 nm; and

(b)a phosphor coating comprising a polymeric binder and particles of a phosphor blend dispersed therein, said coating being disposed in a direction of radiation emitted from said LEDs, said phosphor blend comprising:

(1)a first phosphor comprising oxides of at least an alkaline-earth metal selected from the group consisting of strontium, barium, calcium, and combinations thereof and oxides of at least a Group-IIIB metal selected from the group consisting of aluminum, gallium, indium, and combination thereof, said phosphor being activated with ions of at least a rare-earth metal comprising at least europium, said phosphor having a formula of $(M_{1-x}RE_x)_yD_2O_4$;

wherein M is said at least an alkaline-earth metal; RE is said rare-earth metal comprising at least europium; D is said at least a Group IIIB metal; $0.001 < x <$

0.3, and y satisfies a condition selected from the group consisting of $0.75 < y < 1$ and $1 < y < 1.1$; and

(2)at least an additional phosphor selected from the group consisting of phosphors that are excitable by radiation having wavelengths in a range from about 315 nm to about 480 nm that have a peak emission in at least one of blue, blue-green, green, yellow-orange, and red light wavelengths.

[c62] 62.The light source according to claim 61, wherein said coating further comprises particles of a light-scattering material.

[c63] 63.The light source according to claim 61 further comprising a seal disposed around a totality of said panel, said LEDs, and said phosphor coating.

[c64] 64.A light source comprising:

(a)a plurality of LEDs attached to a reflective panel, said LEDs being capable of emitting a radiation having wavelengths in a range from about 315 nm to about 480 nm; and

(b)a phosphor coating comprising a polymeric binder and particles of a phosphor blend dispersed therein, said coating being disposed in a direction of radiation emitted from said LEDs, said phosphor blend comprising $Sr_{0.8}Eu_{0.1}Al_{2+2}O_4$, $Ca_5(PO_4)_3Cl:Mn^{2+},Eu^{2+}$, and $(Sr,Ba,Ca)_5(PO_4)_3(Cl,OH):Eu$.